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Kimura et al.

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(54) **RADIO COMMUNICATION APPARATUS AND COMMUNICATION METHOD**

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(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

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Related U.S. Application Data

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(51) **Int. Cl.**
H04L 27/28 (2006.01)
H04B 1/69 (2006.01)

(52) **U.S. Cl.** **375/260**; 375/130

(58) **Field of Classification Search** 375/260, 375/130, 261, 354; 370/208, 210, 355
See application file for complete search history.

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(57) **ABSTRACT**

In a radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, a receive state acquisition section acquires a receive state of each mobile station, a frame format decision section decides a frame format of which guard interval length is, different for each slot based on the receive state of each mobile station, a slot assignment section assigns each slot of the frame format to data for each mobile station, and a frame format reporting section reports the decided frame format to the mobile stations via a reporting channel. The mobile station identifies the GI length based on the reported frame format and the slot number, removes the guard interval, and performs processing.

23 Claims, 16 Drawing Sheets

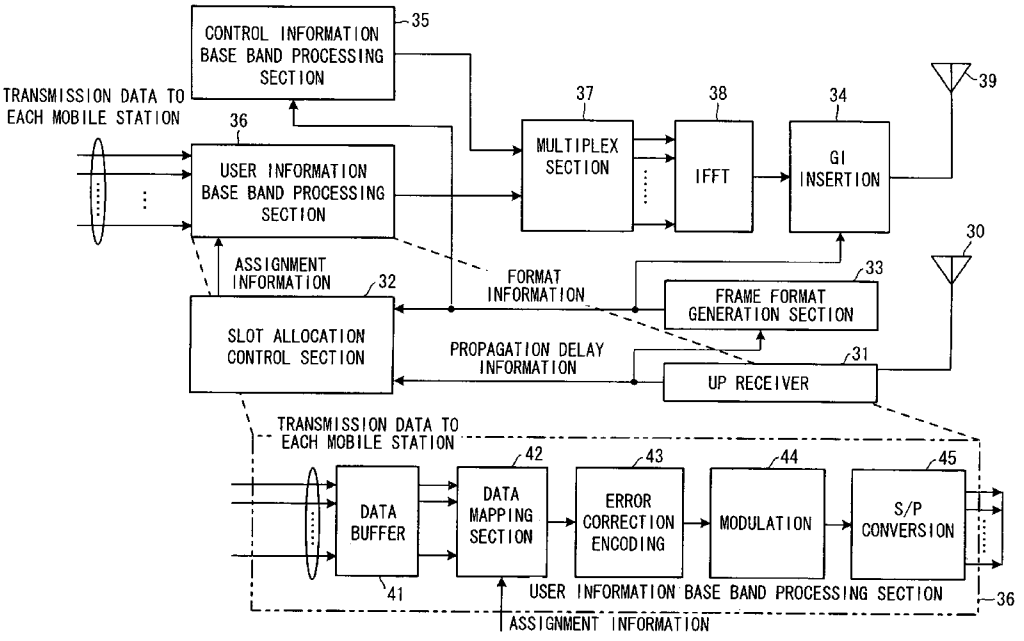


FIG. 1

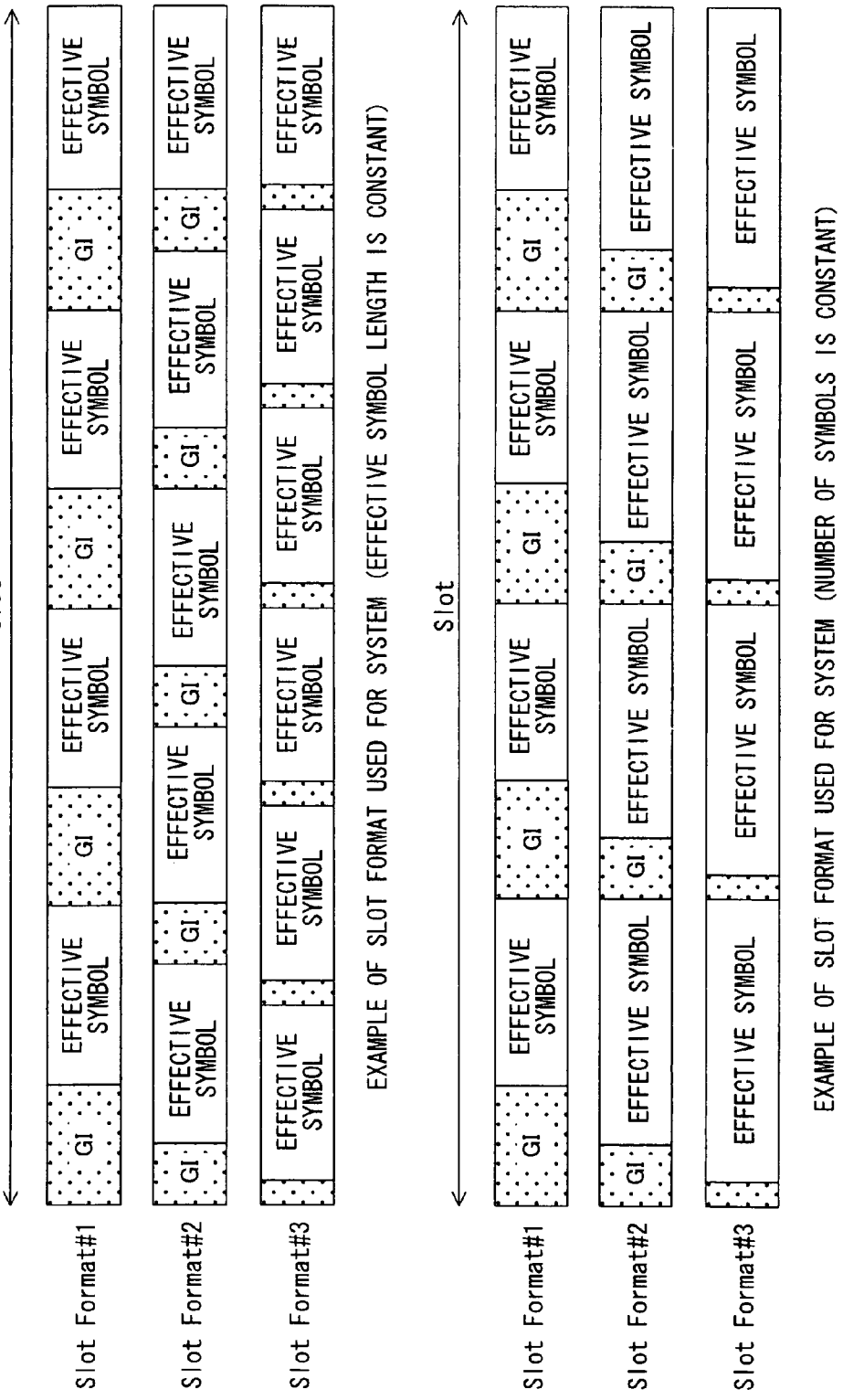

(A)
Slot
Slot Format#1
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
Slot Format#2
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
Slot Format#3
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EXAMPLE OF SLOT FORMAT USED FOR SYSTEM (EFFECTIVE SYMBOL LENGTH IS CONSTANT)
(B)
Slot
Slot Format#1
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
Slot Format#2
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
GI
EFFECTIVE SYMBOL
Slot Format#3
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EFFECTIVE SYMBOL
EXAMPLE OF SLOT FORMAT USED FOR SYSTEM (NUMBER OF SYMBOLS IS CONSTANT)

FIG. 2

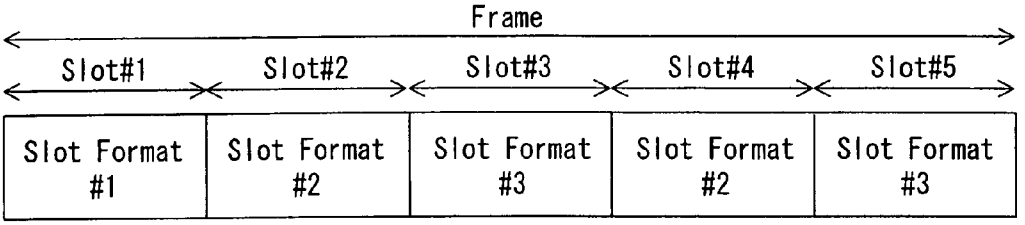

Frame
Slot#1
Slot#2
Slot#3
Slot#4
Slot#5
Slot Format #1
Slot Format #2
Slot Format #3
Slot Format #2
Slot Format #3

FIG. 3

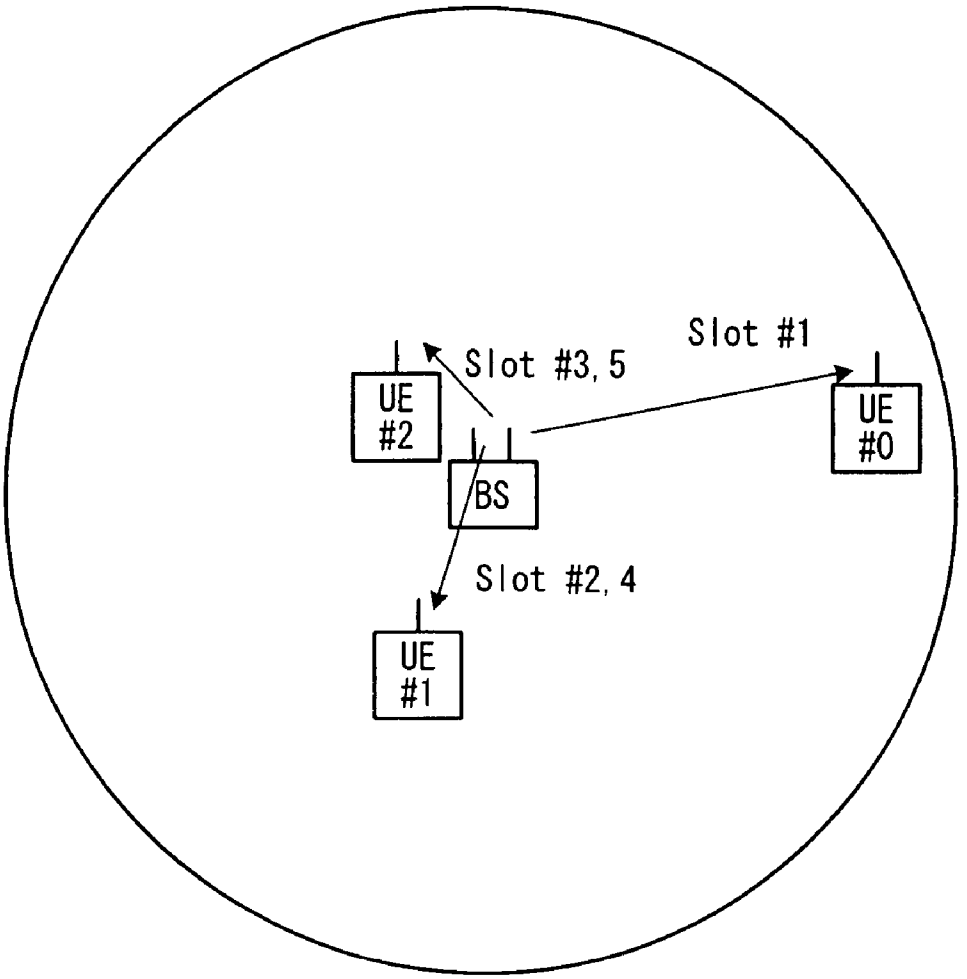


FIG. 4

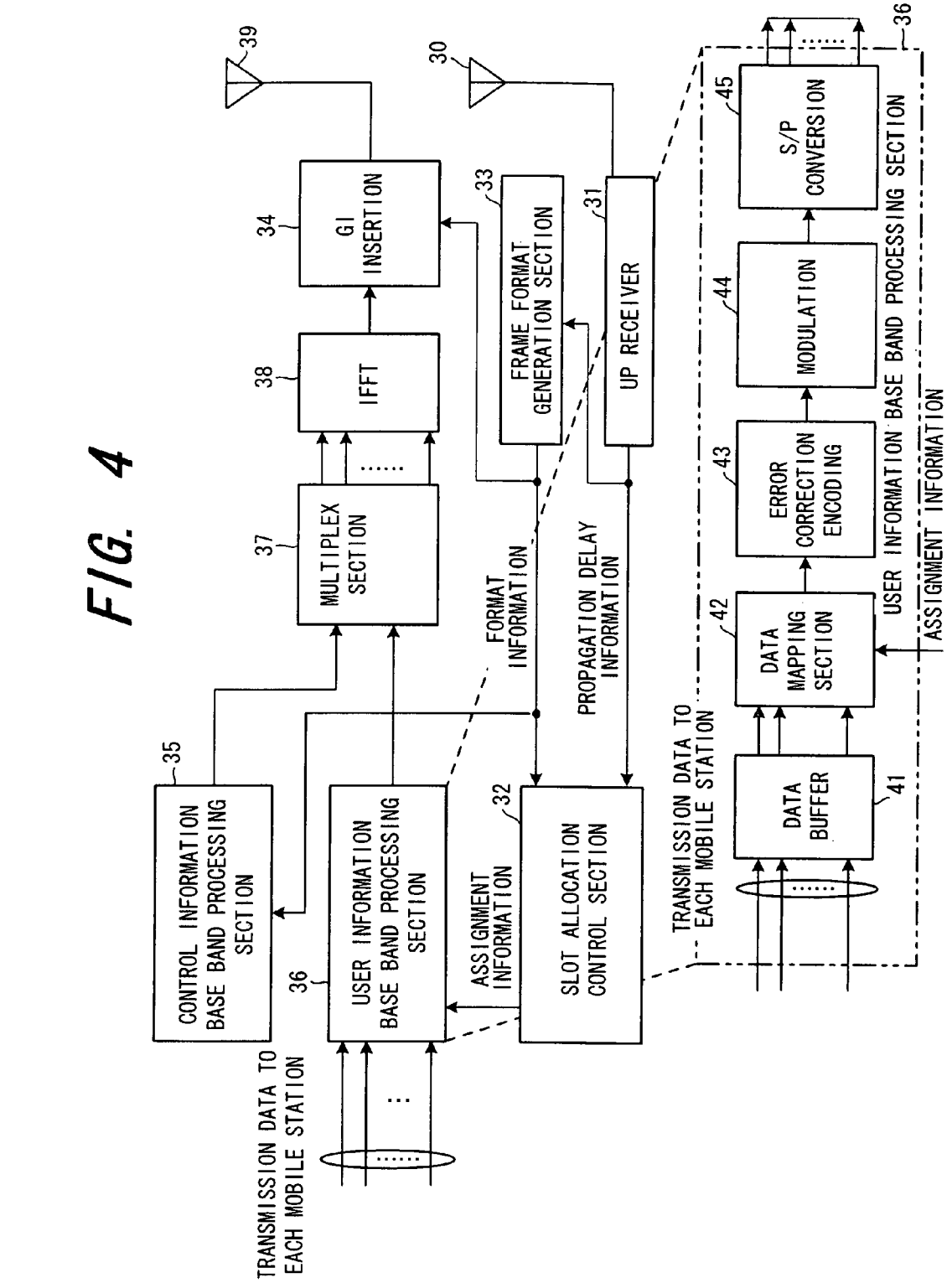

39
30
36
45
S/P CONVERSION
34
GI INSERTION
33
FRAME FORMAT GENERATION SECTION
31
UP RECEIVER
44
MODULATION
38
IFFT
43
ERROR CORRECTION ENCODING
37
MULTIPLEX SECTION
FORMAT INFORMATION
PROPAGATION DELAY INFORMATION
42
DATA MAPPING SECTION
USER INFORMATION BASE BAND PROCESSING SECTION
ASSIGNMENT INFORMATION
35
CONTROL INFORMATION BASE BAND PROCESSING SECTION
36
USER INFORMATION BASE BAND PROCESSING SECTION
ASSIGNMENT INFORMATION
32
SLOT ALLOCATION CONTROL SECTION
TRANSMISSION DATA TO EACH MOBILE STATION
41
DATA BUFFER
TRANSMISSION DATA TO EACH MOBILE STATION

FIG. 5

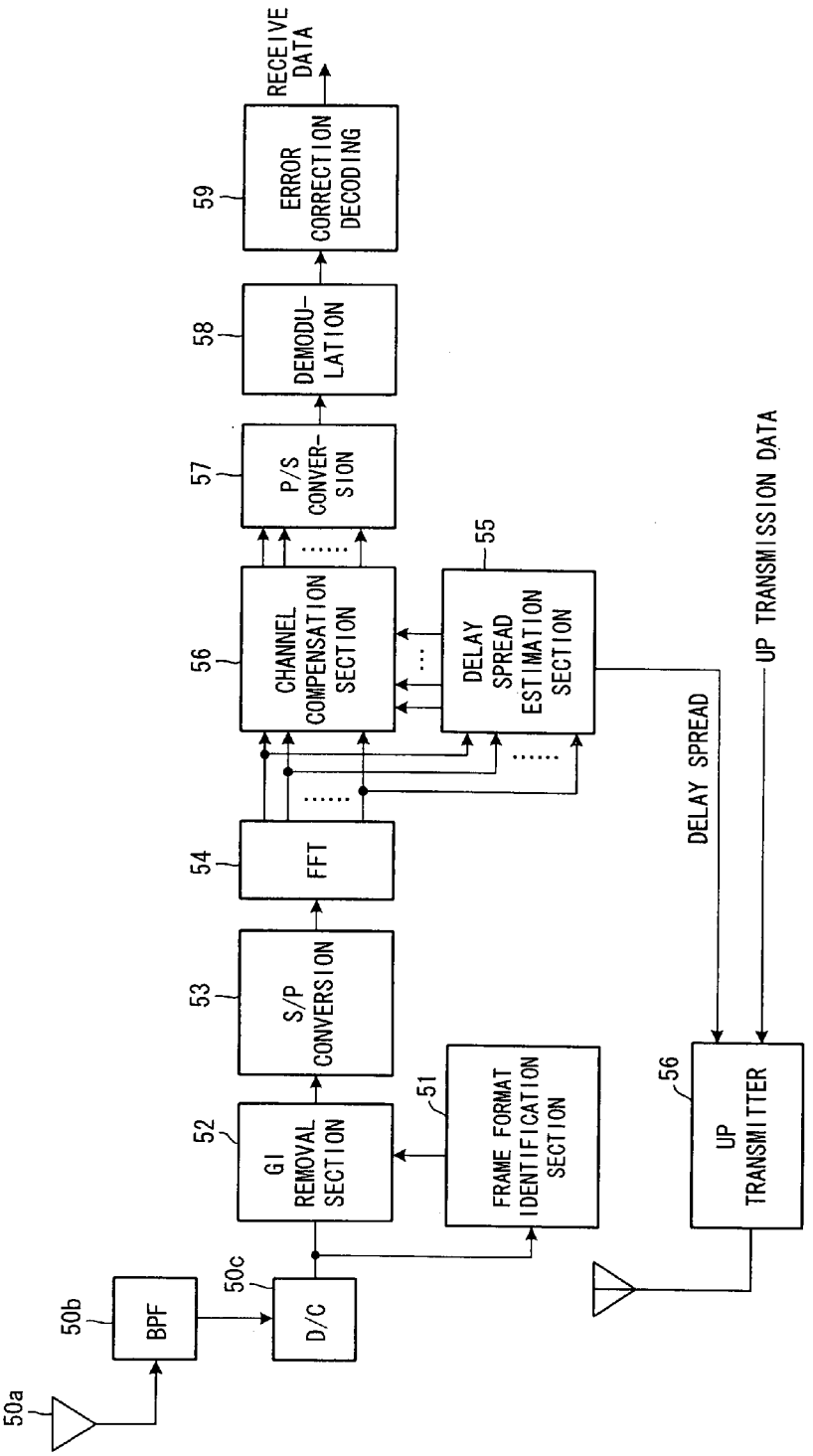

50a
50b
BPF
50c
D/C
52
GI REMOVAL SECTION
51
FRAME FORMAT IDENTIFICATION SECTION
53
S/P CONVERSION
54
FFT
56
CHANNEL COMPENSATION SECTION
55
DELAY SPREAD ESTIMATION SECTION
57
P/S CONVER-SION
58
DEMODU-LATION
59
ERROR CORRECTION DECODING
RECEIVE DATA
DELAY SPREAD
UP TRANSMISSION DATA
56
UP TRANSMITTER

FIG. 6

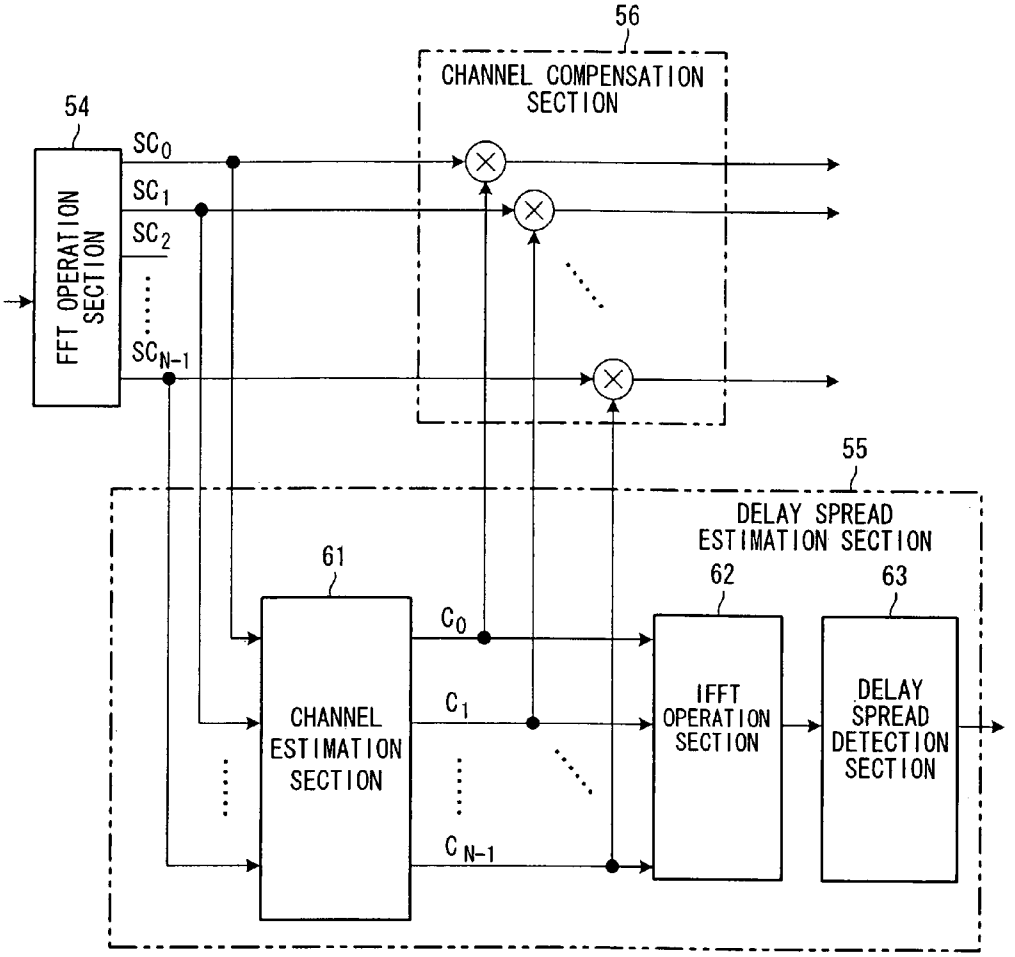

56
CHANNEL COMPENSATION SECTION
54
FFT OPERATION SECTION
SC0
SC1
SC2
SCN-1
55
DELAY SPREAD ESTIMATION SECTION
61
62
63
C0
C1
CN-1
CHANNEL ESTIMATION SECTION
IFFT OPERATION SECTION
DELAY SPREAD DETECTION SECTION

FIG. 7

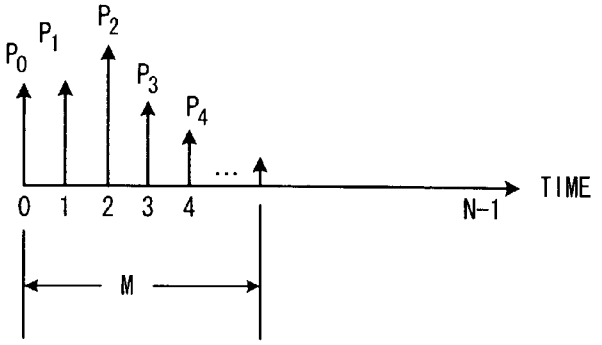

P0
P1
P2
P3
P4
TIME
0
1
2
3
4
N-1
M

FIG. 8

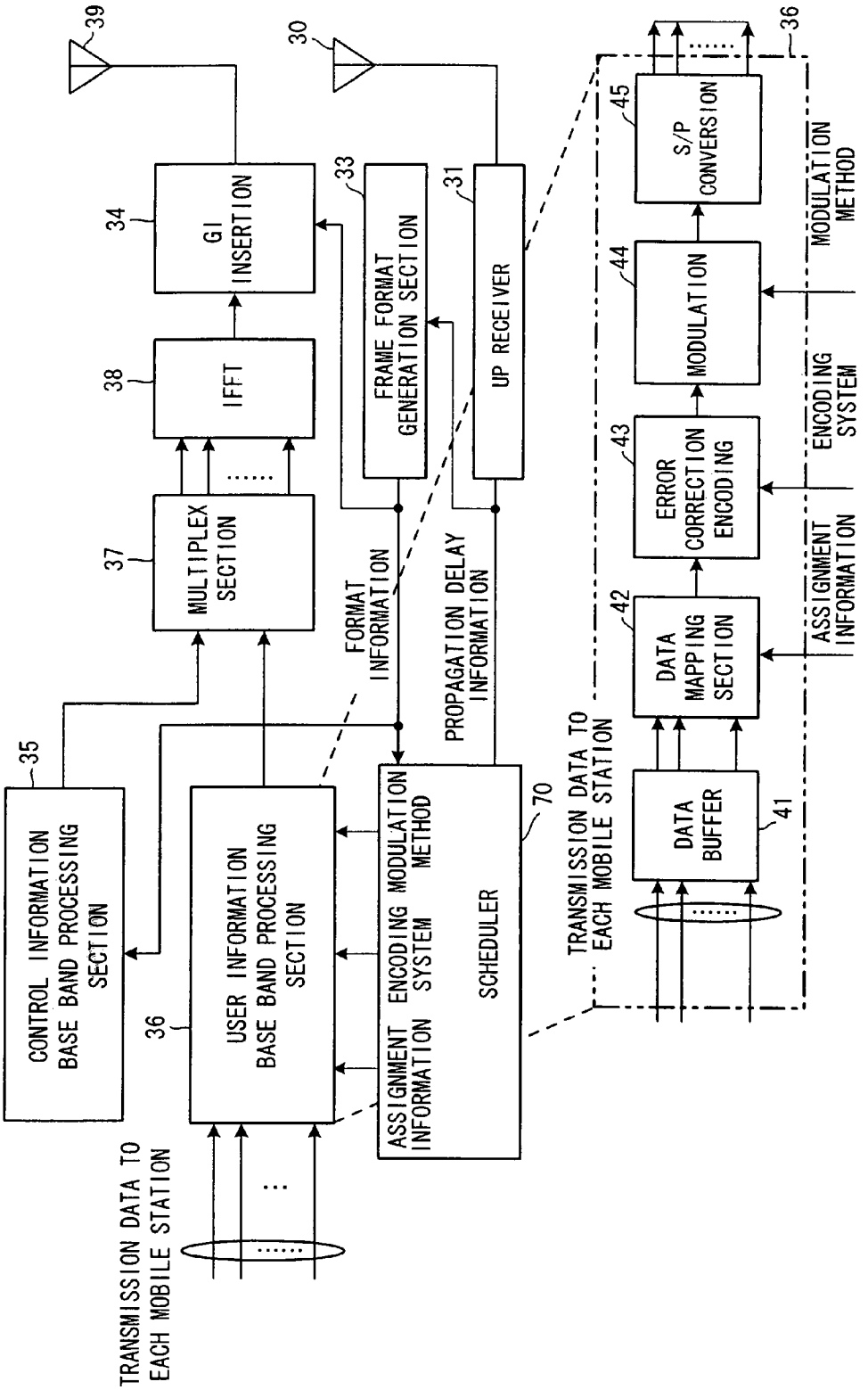

39
30
36
45
S/P CONVERSION
34
GI INSERTION
33
FRAME FORMAT GENERATION SECTION
31
UP RECEIVER
44
MODULATION
MODULATION METHOD
38
IFFT
43
ERROR CORRECTION ENCODING
ENCODING SYSTEM
37
MULTIPLEX SECTION
FORMAT INFORMATION
PROPAGATION DELAY INFORMATION
42
DATA MAPPING SECTION
ASSIGNMENT INFORMATION
35
CONTROL INFORMATION BASE BAND PROCESSING SECTION
36
USER INFORMATION BASE BAND PROCESSING SECTION
ASSIGNMENT INFORMATION
ENCODING SYSTEM
MODULATION METHOD
SCHEDULER
70
TRANSMISSION DATA TO EACH MOBILE STATION
DATA BUFFER
41
TRANSMISSION DATA TO EACH MOBILE STATION

FIG. 9

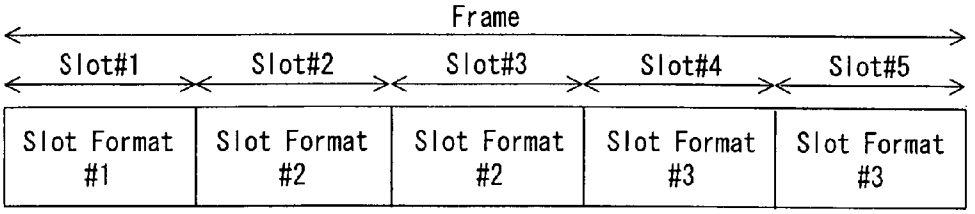

Frame
Slot#1
Slot#2
Slot#3
Slot#4
Slot#5
Slot Format #1
Slot Format #2
Slot Format #2
Slot Format #3
Slot Format #3

FIG. 10

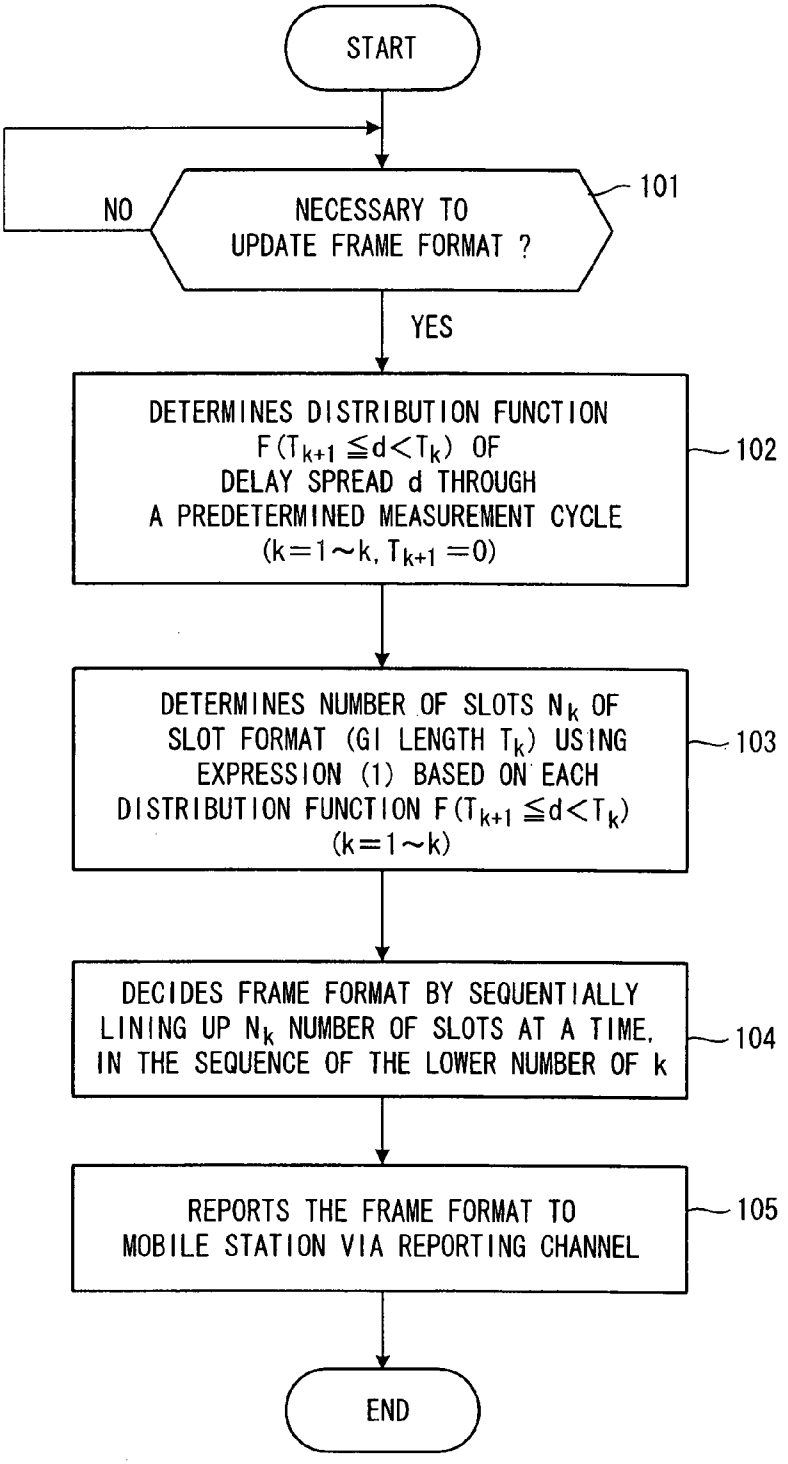

START
NO
NECESSARY TO UPDATE FRAME FORMAT ?
101
YES
DETERMINES DISTRIBUTION FUNCTION $F(T_{k+1} \leqq d < T_k)$ OF DELAY SPREAD d THROUGH A PREDETERMINED MEASUREMENT CYCLE ($k=1 \sim k$, $T_{k+1}=0$)
102
DETERMINES NUMBER OF SLOTS N_k OF SLOT FORMAT (GI LENGTH T_k) USING EXPRESSION (1) BASED ON EACH DISTRIBUTION FUNCTION $F(T_{k+1} \leqq d < T_k)$ ($k=1 \sim k$)
103
DECIDES FRAME FORMAT BY SEQUENTIALLY LINING UP N_k NUMBER OF SLOTS AT A TIME, IN THE SEQUENCE OF THE LOWER NUMBER OF k
104
REPORTS THE FRAME FORMAT TO MOBILE STATION VIA REPORTING CHANNEL
105
END

FIG. 11

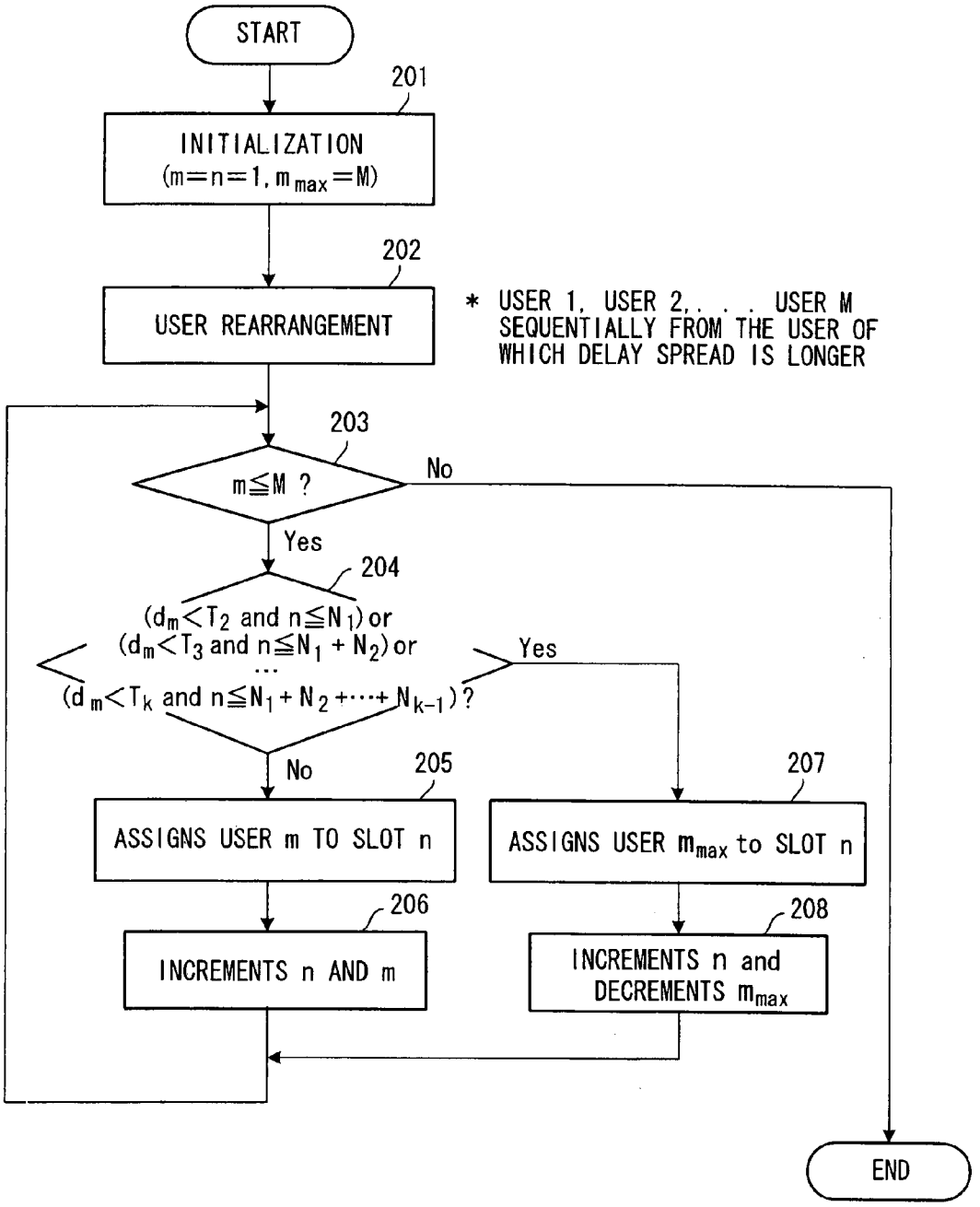

START
201
INITIALIZATION
(m=n=1, m max=M)
202
USER REARRANGEMENT
* USER 1, USER 2, . . . USER M SEQUENTIALLY FROM THE USER OF WHICH DELAY SPREAD IS LONGER
203
m≦M ?
No
Yes
204
(dm<T2 and n≦N1) or
(dm<T3 and n≦N1 + N2) or
...
(dm<Tk and n≦N1 + N2 +...+ Nk-1) ?
Yes
No
205
ASSIGNS USER m TO SLOT n
207
ASSIGNS USER mmax to SLOT n
206
INCREMENTS n AND m
208
INCREMENTS n and
DECREMENTS mmax
END

FIG. 12

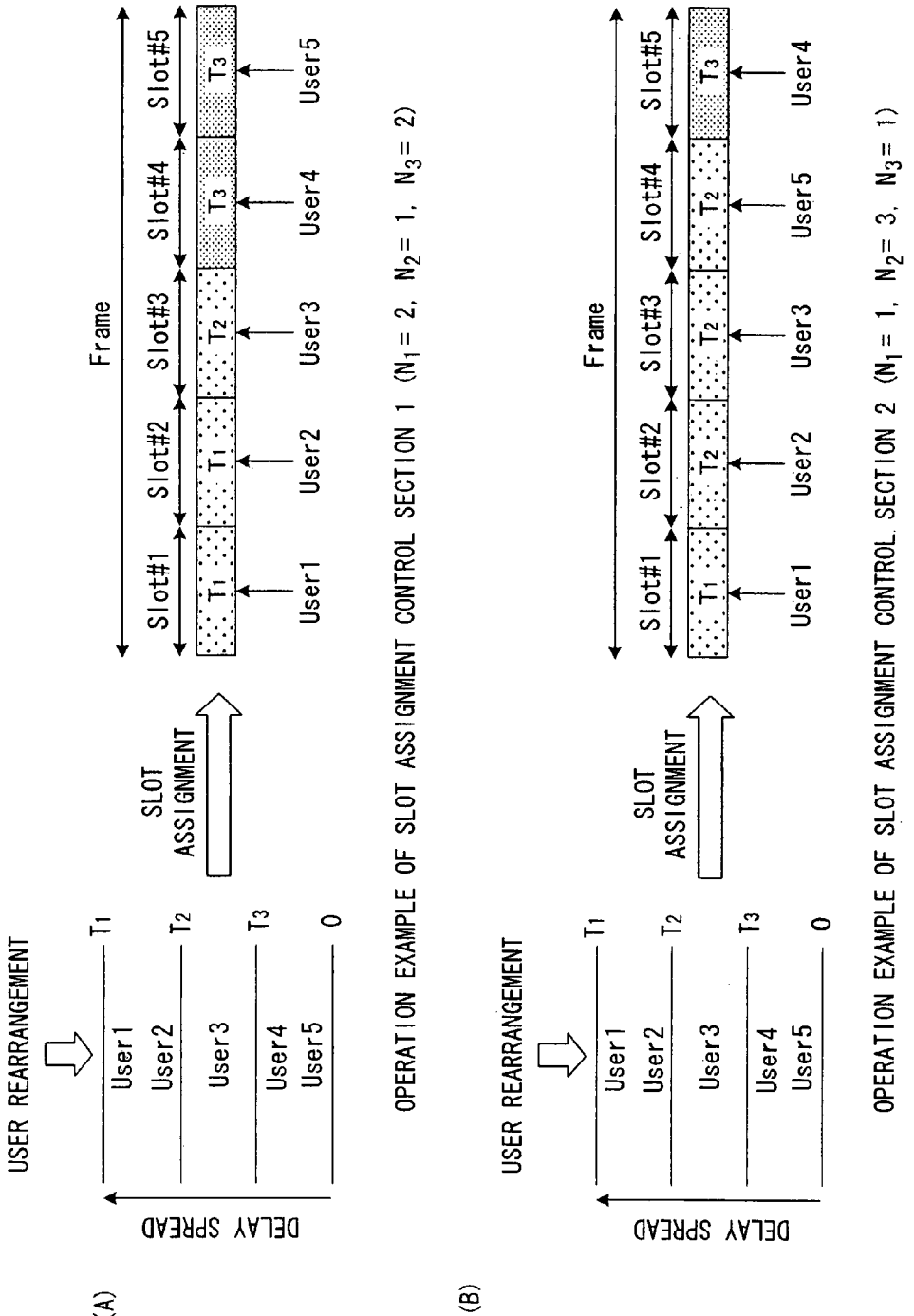

(A)
USER REARRANGEMENT
T1
User1
User2
T2
User3
T3
User4
User5
0
DELAY SPREAD
SLOT ASSIGNMENT
Frame
Slot#1
Slot#2
Slot#3
Slot#4
Slot#5
T1
T1
T2
T3
T3
User1
User2
User3
User4
User5
OPERATION EXAMPLE OF SLOT ASSIGNMENT CONTROL SECTION 1 (N1= 2, N2= 1, N3= 2)
(B)
USER REARRANGEMENT
T1
User1
User2
T2
User3
T3
User4
User5
0
DELAY SPREAD
SLOT ASSIGNMENT
Frame
Slot#1
Slot#2
Slot#3
Slot#4
Slot#5
T1
T2
T2
T2
T3
User1
User2
User3
User5
User4
OPERATION EXAMPLE OF SLOT ASSIGNMENT CONTROL SECTION 2 (N1= 1, N2= 3, N3= 1)

FIG. 13

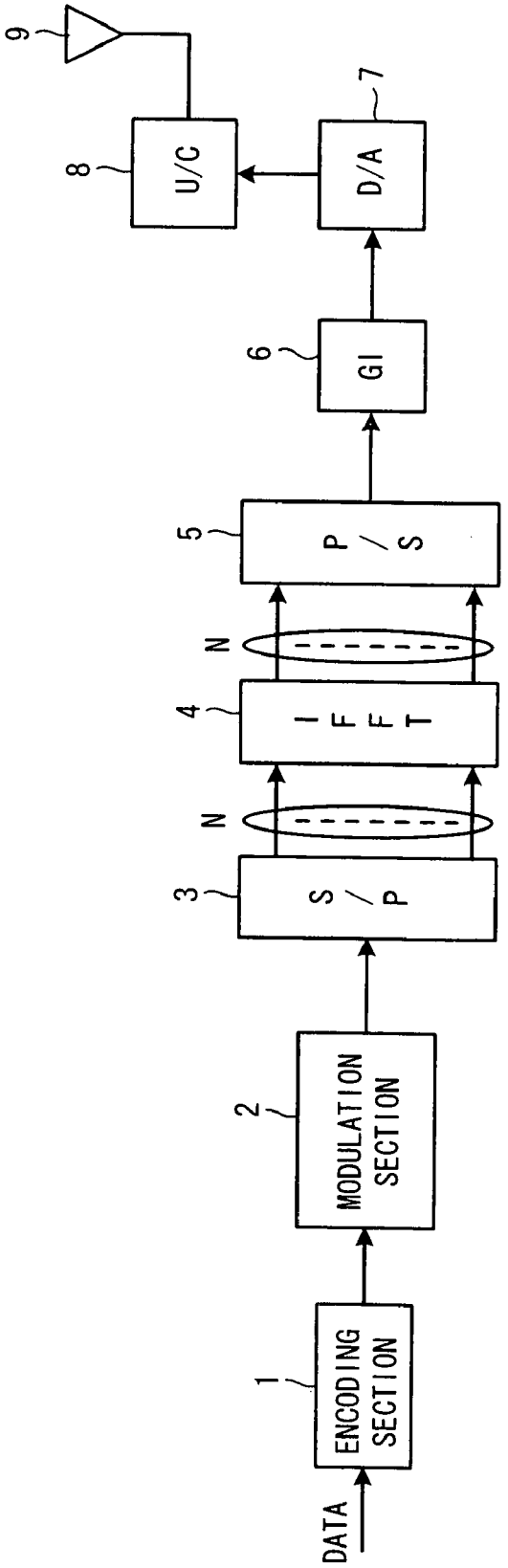

DATA
1
ENCODING SECTION
2
MODULATION SECTION
3
S / P
N
4
I F F T
N
5
P / S
6
GI
7
D/A
8
U/C
9

FIG. 14 PRIOR ART

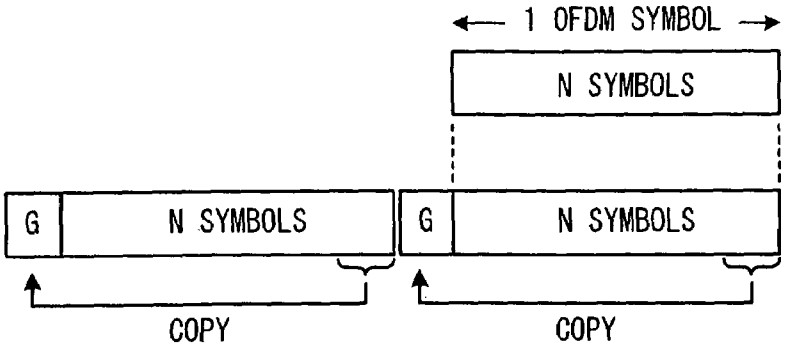


FIG. 15 PRIOR ART

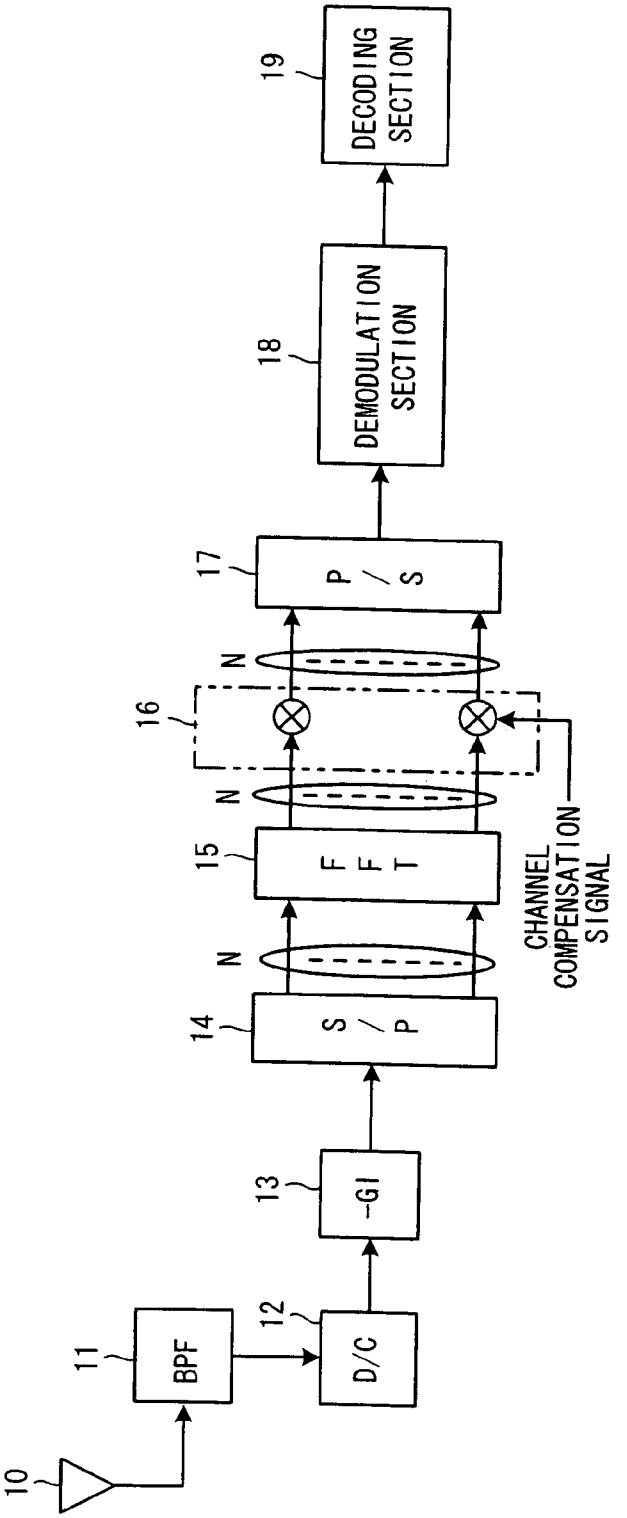


FIG. 16 PRIOR ART

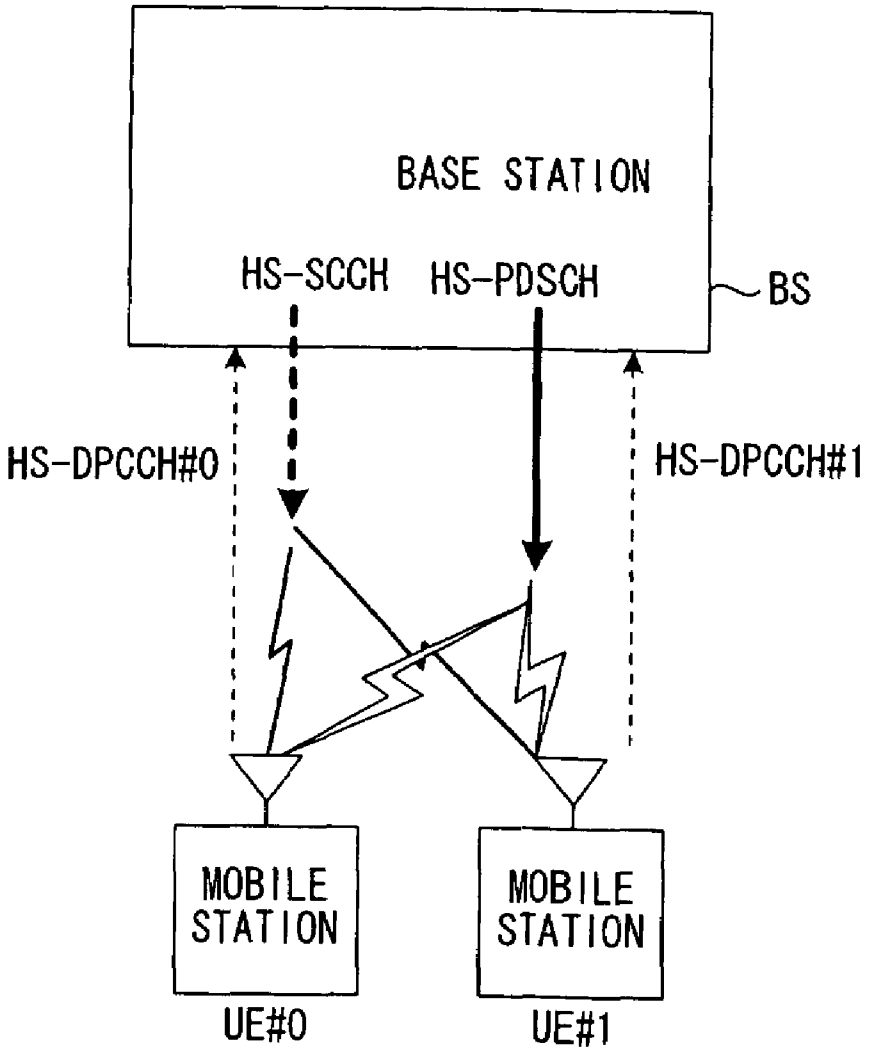
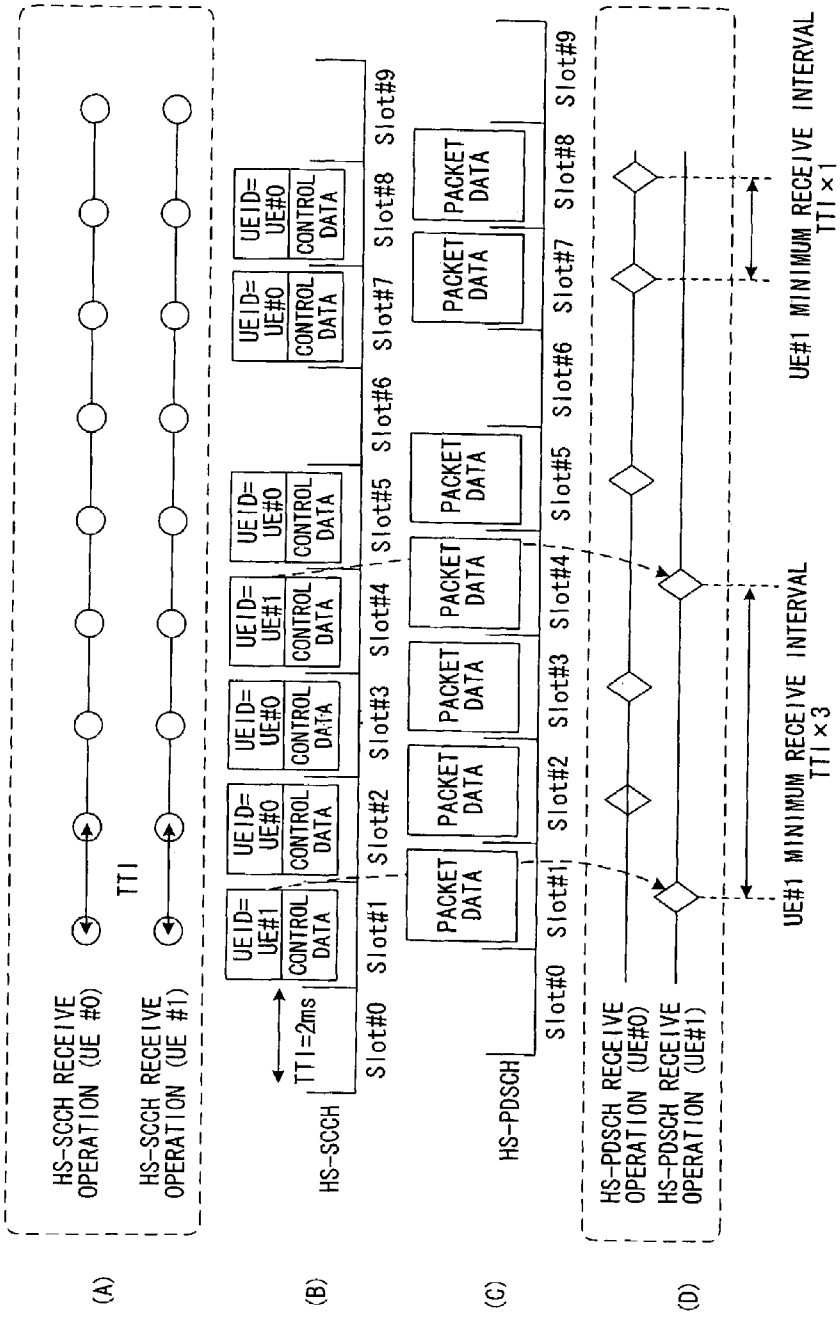


FIG. 17 PRIOR ART



RADIO COMMUNICATION APPARATUS AND COMMUNICATION METHOD

This application is a continuation PCT Application No. PCT/JP04/18611, filled Dec. 14, 2004, the entire contents of which are incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention relates to a radio communication apparatus and a communication method, and more particularly to a radio communication apparatus and a communication method for forming a frame with a plurality of slots and inserting a guard interval into each slot along with data for a mobile station to perform communication.

An example of a radio communication system using a guard interval is an orthogonal frequency division multiplexing (OFDM) radio communication system. An OFDM radio communication system is a system which multiplies each of a plurality of orthogonal frequencies (sub-carriers) by a symbol (data), then performs inverse Fourier transform, and since the sub-carriers are orthogonal to one another on the frequency axis, a symbol can be individually acquired for each sub-carrier by performing Fourier transform at the receive side.

OFDM Transmitter

FIG. **13** is a block diagram depicting an OFDM transmitter in a conventional OFDM radio communication system. An encoding section **1** encodes high-speed binary data using convolutional encoder or turbo encoder, and a modulation section **2** modulates the encoded data after interleave, using M-bits modulation such as BPSK, QPSK or 16-QAM, for example. Then a serial/parallel converter (S/P converter) **3** converts the modulated data symbol into N symbols of parallel modulated data symbols, and generates N number of sub-carrier components.

N points of inverted fast Fourier transform section **4** performs inverted Fourier transform processing (IFFT) on N number of modulated signals (sub-carrier components), which are output from the S/P converter **3**, and outputs N number of time signal components in parallel. A parallel/serial converter (P/S converter) **5** converts the N number of time signal components acquired by the IFFT processing into serial data, and outputs them as an OFDM symbol. A guard interval insertion section **6** inserts a guard interval GI into this OFDM symbol, a digital/analog converter (D/A) converts the output signal from the guard interval insertion section into an analog signal, and a radio section **8** up-converts the frequency of the base band signal into a radio signal, then amplifies and transmits the radio signal into a space by an antenna **9**. In the following description, a case of using fast Fourier transform FFT and inverted fast Fourier transform IFFT are used for Fourier transform and inverted Fourier transform will be described, but discrete Fourier transform DFT and inverted discrete Fourier transform IDFT may be used.

FIG. **14** is a diagram depicting a guard interval insertion. A guard interval insertion means that the end part of the OFDM symbol is copied and added to the beginning thereof. By inserting a guard interval GI, the influence of inter-signal interference ISI caused by multi-paths can be eliminated.

OFDM Receiver

FIG. **15** is a block diagram depicting an OFDM receiver in the OFDM radio communication system. A band pass filter (BPF) **11** performs filtering on a signal received by an antenna **10** to remove an unnecessary frequency component, a down-converter (D/C) **12** converts the frequency of a radio signal into a base band frequency, an analog/digital converter (not illustrated) converts the analog of the base band signal into digital, and a guard interval removal section **13** removes the guard interval. An S/P converter **14** converts a time signal, after the guard interval is removed, into N number of parallel data, and inputs the data to N points of the Fourier transform section **15**. The Fourier transform section **15** performs N points of FFT processing on the N number of time signal components, and outputs N number of sub-carrier components. A channel estimation section (not illustrated) performs a known channel estimation operation and estimates channel coefficients of each sub-carrier, and generates a channel compensation value, and a channel compensation section **16** multiplies N number of FFT processing results by the channel compensation value so as to decrease the influence of channel distortion. Finally, a P/S converter **17** outputs N number of sub-carrier components after channel compensation is performed, sequentially in serial, a demodulation section **18** demodulates the input signal using BPSK, QPSK or 16-QAM, for example, and a decoding section **19** decodes and outputs the input data after deinterleave.

Prior Art

In radio communication, multi-paths, where a plurality of reflected waves reach the receiver via different routes, are a problem. If different reflected waves reach a receiver with certain time differences, inter-symbol interference occurs due to the overlap of time adjacent symbols, which deteriorates the bit error performance. In order to prevent this, inserting a guard interval is effective, which is not limited to OFDM. In the case of OFDM, as described in FIG. **14**, it is common that the end part of the OFDM symbol is copied and added to the beginning thereof as a guard interval. If the maximum delay due to multi-paths is smaller than the guard interval length, inter-symbol interference due to multi-paths can be completely removed. In this case, as the guard interval length is longer, greater influence of the delay path can be removed, but transmission efficiency, that is, bit rate decreases. Therefore it is desirable to set the guard interval length to the length of the maximum path delay. However, in the case of applying the OFDM radio communication system to a cellular system, various cell arrangements and cell radiuses must be supported, and it is impossible to determine a guard interval length which is optimum for the entire system. Also, even within a cell, an optimum guard interval length differs since the distribution of multi-paths is different depending on the location of mobile stations.

Because of this, a radio communication system which can apply a plurality of guard interval lengths was proposed, and the adaptive control of the guard interval length, depending on the radio state, has been performed. A first prior art is a system where a base station determines a guard interval length and reports this guard interval length to mobile stations, and is disclosed in JP 2000-244441A, and JP 2001-69110A.

A second prior art is a system where a mobile station determines a guard interval length and reports this guard interval length to a base station, and the base station transmits a downlink signal using the guard interval length specified by the mobile station, and is disclosed in JP 2003-152670A, and JP 10-327122A.

A third prior art is a system where a mobile station detects a guard interval length in the blind (blind detection), and is disclosed in JP 2002-247005A and JP 2002-374223A.

Applying these prior arts to a radio communication system having scheduling and adaptive modulation functions will be considered. In such a radio communication system, a base station estimates a receive quality of each mobile station by some means, and decides the assignment of data transmission to each mobile station, the modulation system for data trans-

mission and coding rate, for each packet timing based on the channel quality. According to this decision, the base station transmits a data packet and transmission control information including mobile station identification number, modulation system, coding rate, to the mobile station. The mobile station can accurately demodulate and decode data packets transmitted to itself by first receiving the transmission control information from the base station and then receiving the data signal using the transmission control information. For example, HSDPA (High-Speed Downlink Packet Access) in W-CDMA and HDR (High Data Rate) in CDMA 2000 use this system.

HSDPA System

FIG. **16** is a diagram depicting a configuration of an HSDPA system. BS is a base station, and UE#**0** and UE#**1** are mobile stations. In an HSDPA system, (1) HS-PDSCH (High-Speed-Physical Downlink Shared Channel) is used as a transmission channel of packet data in a downlink radio interval. This downlink data channel is shared by a plurality of mobile stations UE#**0**, UE#**1**, ... Also in the downlink radio interval, (2) HS-SCCH (High-Speed Shared Control Channel) is used as a high-speed control channel, and mobile stations UE#**0** and UE#**1** receives control information required for receiving packet data on HS-PDSCH. This HS-SCCH is shared by a plurality of mobile stations UE#**0**, UE#**1** . . . . In the uplink radio channel, (3) HS-DPCCH (High-Speed Dedicated Physical Control Channel) is set for each user as a high-speed control channel for transmitting feedback information. In the HSDPA system, data retransmission control is performed between the base station BS and the mobile stations UE#**0**, UE#**1**, . . . , and the mobile stations UE#**0**, UE#**1** . . . report ACK (acknowledgement) and NACK (not acknowledgement) depending on the decoding result of the received data to the base station BS using the above HS-DPCCH.

(A) to (D) of FIG. **17** are diagrams depicting the packet data receive mechanism of HS-PDSCH.

A transmission cycle called TTI (Transmission Time Interval=2 ms) is set on HS-SCCH, as shown in (A) of FIG. **17**, and only when control information to transmit exists, this control information is transmitted from the base station BS at TTI, and is received by the mobile stations UE#**0** and UE#**1**. The control data to be transmitted via HS-SCCH is, for example, a user identifier (UEID: User Equipment Identifier) and various parameters (e.g. spreading code, modulation scheme, data length) required for receiving data of HS-PDSCH.

The mobile stations UE#**0** and UE#**1** can receive HS-SCCH data at all the TTIs. For example, at slot #**1** in (B) of FIG. **17**, UE#**0** and UE#**1** receive HS-SCCH data simultaneously. Here mobile station UE#**0** and UE#**1** refer to the UEID in the data, and compares it with their own ID. In this case, the UEID of the HS-SCCH data in slot #**1** is UE#**1**, so the mobile station UE#**0** discards the received HS-SCCH data, and the mobile station UE#**1** holds the control data in the received HS-SCCH data. Then the mobile station UE#**1** extracts the parameter for receiving HS-PDSCH from the control data, and receives the packet data on HS-PDSCH ((C) and (D) of FIG. **17**).

After receiving the data, the mobile station UE#**1** refers to the CRC bit included in the data and judges whether the packet was successfully decoded without block error. If the data was received without block error, the mobile station UE#**1** reports ACK to the base station BS using HS-DPCCH. If there is a block error, the mobile station UE#**1** reports NACK to the base station BS using HS-DPCCH. This is the same for slots #**2-5**, and slots. #**7-8**, and the mobile station UE#**1** receives the packet data via HS-PDSCH of slots #**1** and #**4**, and the mobile station UE#**0** receives packet data via HS-PDSCH of slots #**2-3**, **5** and **7-8**.

Problems of Prior Art

If the first prior art is used for the radio communication system, the base station must report the guard interval length to the mobile station. However, the guard interval length, which is a basic parameter required for performing FFT for OFDM, must be known first to receive data. Therefore a method of reporting the guard interval length is a critical issue. Also, if a plurality of mobile stations are time-multiplexed as in the case of the above radio communication system, users are frequently switched, which means that the guard interval length must be frequently switched, and the mobile stations must judge the guard interval length for each packet. As a result, in each mobile station, a processing delay becomes a problem and the circuit size increases. In the base station, on the other hand, data transmission efficiency decreases because frequent transmission of information of the guard interval length is needed, and power consumption for transmitting control information increases.

If the second prior art is used for a radio communication system, a mobile station voluntarily determines a guard interval, and knows a guard interval before demodulation, so the problem of the first prior art does not exist. However, the reliability of the reported guard interval length from the mobile station to the base station must be increased, so highly efficient encoding is required for mobile stations, which increases the processing volume and power consumption, and makes the circuit complicated. Also the base station must adhere to the guard interval length specified by the mobile station, which is not desirable in terms of system management.

If the third prior art is used, highly reliable blind detection is required, which increases the processing volume of the mobile station and the power consumption, and requires a larger circuit scale accordingly. Also if a detection error is generated, the receive characteristic deteriorates, so it is difficult to implement this prior art.

SUMMARY OF THE INVENTION

With the foregoing in view, it is an object of the present invention to provide a radio communication device and a communication method which need not frequently report a guard interval length from the base station to a mobile station in a communication system which can use a plurality of guard interval lengths.

It is another object of the present invention to provide a radio communication device and a communication method for improving the data transmission efficiency and decreasing the power consumption.

In a radio communication device for a system which have a frame structure formed by a plurality of slots with guard interval, a receive state acquisition section acquires a receive state of each mobile station, a frame format decision section decides a frame format of which guard interval length is different for each slot based on the receive state of each mobile station, a slot assignment section assigns each slot of the frame format to data for each mobile station, and a frame format reporting section reports the decided frame format to each mobile station via a reporting channel.

The receive state acquisition section acquires a delay spread as a receive state of each mobile station, and the frame format decision section (1) prepares a plurality of slot formats of which guard interval lengths are different in advance, (2) determines the distribution of the delay spread based on the delay spread of each mobile station, and (3) assigns a prede-

termined slot format to each slot constituting the frame according to the distribution of the delay spread to determine the frame format.

The frame format decision section judges whether it is necessary to update the decided frame format, and updates the frame format if update is necessary, and the slot assignment section assigns each slot of the frame format to each mobile station based on a delay spread of each mobile station in a cycle shorter than the update period.

The slot assignment section assigns mobile station data with small path delay with priority if the mobile station data cannot be assigned to an optimum slot due to the deviation of a delay spread distribution of the mobile station.

The slot assignment section also assigns mobile station data to a slot even if the guard interval is smaller than the path delay if the mobile station data cannot be assigned to an optimum slot due to the deviation of a delay spread distribution of the mobile station.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** are diagrams depicting the slot formats of the present invention;

FIG. **2** is a diagram depicting a frame format of the present invention;

FIG. **3** is a diagram depicting an example of assigning mobile stations to each slot;

FIG. **4** is a block diagram depicting a base station of the present invention;

FIG. **5** is a block diagram depicting a mobile station of the present invention;

FIG. **6** is a block diagram depicting a delay spread estimation section;

FIG. **7** is a diagram depicting a delay profile and delay spread;

FIG. **8** is a block diagram depicting a base station when the slot assignment control section is replaced with a scheduler section;

FIG. **9** is a diagram depicting an example of a frame format when N_{slot}=5, K=3, N_1=1, N_2=N_3=2;

FIG. **10** is a flow chart depicting a frame format generation processing;

FIG. **11** is a flow chart depicting a slot assignment processing;

FIG. **12** are diagrams depicting operation examples of the slot assignment control;

FIG. **13** is a block diagram depicting an OFDM transmitter in a conventional OFDM radio communication system;

FIG. **14** is a diagram depicting a guard interval insertion;

FIG. **15** is a block diagram depicting an OFDM receiver in the OFDM radio communication system;

FIG. **16** is a diagram depicting a channel of the HSDPA system; and

FIG. **17** are diagrams depicting a receive mechanism of a packet data on HS-PDSCH.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(A) Overview of Present Invention

The present invention relates to a radio communication using a guard interval, wherein a plurality of slot formats having different guard interval lengths are available and those slot formats arrayed on a time axis in each cell or each sector constitute a frame format which is unique to the cell or sector. Then considering the delay spread of the mobile station, a slot corresponding to an optimum guard interval length is assigned to mobile station data, so as to improve throughput.

FIG. **1** is a diagram depicting the slot format of the present invention. A plurality of slot formats of which guard interval lengths are different are prepared, as shown in (A) or (B) of FIG. **1**. In the examples of (A) and (B) of FIG. **1**, three types of slot formats, Slot Format #**1**-Slot Format #**3**, are provided, and the guard interval length becomes smaller in the sequence of Slot Format #**1**→Slot Format #**2**→Slot Format #**3**. The number of slot formats is not limited to three. (A) of FIG. **1** is an example in a case where an effective symbol length of each slot format, of which guard interval length is different, is constant, and (B) of FIG. **1** is an example in a case where a total length of an effective symbol and guard interval length is constant.

Each base station selects a predetermined number of slot formats out of these plurality of slot formats based on the receive state (e.g. delay spread) of the mobile station for each cell or sector which this base station covers, arrays these slot formats on the time axis, as shown in FIG. **2**, and uses this as a frame format of the cell (sector). In FIG. **2**, a frame consists of five slots, and Slot Format #**1** of which guard interval length is the longest is assigned to the first slot (Slot #**1**), Slot Format #**2** of which guard interval length is the second longest is assigned to the second and fourth slots (Slot #**2**, Slot #**4**), and Slot Format. #**3** of which guard interval is the smallest is assigned to the third and fifth slots (Slot #**3**, Slot #**5**). This combination of frame formats is changed in a relatively long cycle, such as in a unit of several seconds.

The base station also has a scheduling function to assign each slot of a frame format to a plurality of mobile stations, and controls so that data is sent to each mobile station with a slot having an optimum guard interval length considering the delay spread of the mobile station. In other words, the base station assigns data for mobile stations to each slot of the frame format so that ISI (Inter Symbol Interference) is not generated based on the latest delay spread of the mobile station in a cycle shorter than the update cycle of the frame format, and sends the data. FIG. **3** is a diagram depicting an example of assigning each slot to a mobile station. The path delay is correlated to a distance from the base stations BS. The mobile station UE#**2** is close to the base station BS and has a small path delay, and therefore can transmit with Slot Format #**3**, and thus Slot #**3** and Slot #**5** are assigned (see FIG. **2**). In the same way, Slot #**2** and Slot #**4** are assigned to the mobile station UE#**1**, and Slot #**1** is assigned to the mobile station UE#**0**. Actually, however, a slot is not decided based on the distance between the base station and the mobile station, but the path delay information (delay spread) is always used to decide the assigned slot, as mentioned later.

The base station also reports the frame format currently in use to a mobile station via a reporting channel. By this, the mobile station can know in advance which slot format is used in each slot of the reported frame format using the internal table. In other words, only by receiving the frame format each time the frame format is updated, the mobile station can identify the slot format of each slot, and can perform demodulation and decoding processing, with deleting the guard interval, based on this slot format.

The delay spread of a mobile station can be known by a delay spread report data from the mobile station, or by detecting an uplink receive state from the mobile station. In an example of the former case, the mobile station estimates the delay spread based on the downlink signal from the base station, quantizes this delay spread, and reports it to the base station. In an example of the latter case, the base station

estimates the delay spread of each mobile station based on the uplink signal of each mobile station using the internal delay spread estimation section.

According to the present invention, it is unnecessary to transmit/receive the guard interval length information frequently, transmission with a semi-optimum guard interval length becomes possible, and throughput can be improved.

(B) Base Station

FIG. **4** is a block diagram depicting a base station of the present invention. An antenna **30** receives uplink data which is sent from each mobile station and inputs it to an uplink receiver **31**, and the uplink receiver **31**, as a receive state acquisition section, demodulates propagation delay information (delay spread) of each mobile station by the receive signal, and inputs the propagation delay information to a slot assignment control section **32** and a frame format generation section **33**. The frame format generation section **33** prepares a plurality of slot formats of which guard interval lengths are different in advance, as shown in (A) and (B) of FIG. **1**, determines a distribution of the delay spread in a predetermined cycle based on the delay spread of each mobile station, assigns a predetermined slot format to each slot constituting the frame according to the distribution of the delay spread, decides a frame format by this (see FIG. **2**), and inputs this frame format to the slot assignment control section **32**, a guard interval insertion section **34** and a control information base band processing section **35**.

The control information base band processing section **35** maps the reported frame format information to the reporting channel, multiplexes it with a user data, and reports the frame format information to all the mobile stations in a cell or a sector.

The slot assignment control section **32** assigns each slot of the decided frame format to data for each mobile station based on the latest delay spread of the mobile station in a cycle shorter than a frame format update cycle, and inputs the assignment information to a data mapping section **42** of a user information base band processing section **36**.

In the user information base band processing section **36**, a data buffer **41** stores data which is sent to a plurality of mobile stations, the data mapping section **42** extracts data for each mobile station sequentially from the first slot in order based on the assignment information which is input from the slot assignment control section **32**, and outputs the data in serial. An error encoding section **43** encodes the data for a mobile station, using convolutional codes or turbo-codes, for example, and a modulation section **44** modulates the encoded data by BPSK, QPSK or 16-QAM, for example, after interleave. Then a serial/parallel converter (S/P converter) **45** converts modulation data symbols into N symbols of parallel data strings and generates N number of sub-carrier components. The slot format has a constant effective symbol length (=N), as shown in (A) of FIG. **1**.

A multiplex section **37** multiplexes data which is input from the user information base band processing section **36** and the control information base band processing section **35** by code division multiplex, for example, and outputs the multiplexed data. An N point inverted fast Fourier transform section **38** performs inverted fast Fourier transform (IFFT) on N number of sub-carrier components which are output from the multiplex section **37**, converts N number of time signal components in serial, and outputs them as an OFDM symbol. The guard interval insertion section **34** determines the guard interval length of each slot based on the frame format reported by the frame format generation section **33**, inserts a guard interval GI having this length into the OFDM symbol which was input, and sends it to the space by an antenna **39** via a digital/analog converter (D/A) and a radio section, which are not illustrated.

As mentioned above, the slot assignment control section **32** assigns each slot of the frame format to the data for a mobile station based on the latest delay spread of the mobile station in a cycle shorter than the frame format update cycle. Therefore there is a probability that an optimum slot may not be able to be assigned to a mobile station due to the deviation of the delay spread distribution of mobile stations generated after the frame format is decided. In such a case, a slot is assigned to a mobile station with small path delay with priority using a method to be mentioned later. Also the slot assignment control is executed considering throughput of the entire system, so that transmission is possible depending on the situation even if the guard interval is smaller than the path delay.

The distribution of a mobile station and delay path environment of a cell change depending on time. Therefore it is preferable that the frame format which is unique to the cell or sector can be updated in a relatively long cycle. For example, the distribution of the delay spread of each mobile station is statistically monitored by the base station, and the frame format is changed accordingly. In other words, the frame format generation section **33** judges whether it is necessary to update the frame format based on the delay spread of each mobile station, and updates the frame format only when update is necessary.

(C) Mobile Station

FIG. **5** is a block diagram of a mobile station of the present invention. A band pass filter **50***b* performs filtering on signals received by an antenna **50***a* and removes unnecessary frequency components, a down converter (D/C) **50***c* converts a radio signal into base band frequency, and an analog/digital converter (not illustrated) converts a base band signal from analog into digital, and inputs it to a frame format identification section **51** and a GI removal section **52**. The frame format identification section **51** extracts and recognizes the frame format information which is sent via a control channel, and inputs it to the GI removal section **52**. The GI removal section **52** identifies the guard interval length of each slot constituting the frame based on the reported frame format information, removes the guard interval for each slot, and outputs the N symbols of an OFDM symbol. An S/P converter **53** converts the signal after the guard interval is removed into N number of parallel data, and inputs it to N points of the Fourier transform section **54**. The Fourier transform section **54** performs N points of FFT processing on N number of time signal components, and outputs N number of sub-carrier components.

A channel estimation section formed in a delay spread estimation section **55** performs a known channel estimation operation, estimates a channel of each sub-carrier, and inputs a channel compensation value to a channel compensation section **56**. The channel compensation section **56** multiplies N number of FFT processing results by a channel compensation value for channel compensation, and a P/S converter **57** sequentially outputs channel-compensated N number of sub-carrier components in serial, and a demodulation section **58** demodulates an input signal using BPSK, QPSK, or 16-QAM, for example, and a decoding section **59** decodes the input data for error correction after deinterleave, and outputs the result. The delay spread estimation section **55** estimates a delay spread, and an uplink transmitter **56** transmits this delay spread to the base station.

FIG. **6** is a block diagram of the delay spread estimation section **55**. The FFT **54** performs FFT operation processing

on OFDM symbol data, and converts it into the number sub-carriers N of signals SC_0-SC_{N-1}. A channel estimation section **61** of the delay spread estimation section **55** performs channel estimation for each sub-carrier using a pilot multiplexed at the transmission side, and outputs channel estimation values C_0-C_{N-1}. In other words, the channel estimation section **61** estimates an amplitude and a phase of each sub-carrier due to fading channel shown by $A_n \exp(j_n\phi)$ (n=1−N) using a pilot signal, and outputs channel compensation values $(1/A_n)\exp(-j_n\phi)$ (n=1−N). Each multiplier of the channel compensation section **56** multiplies the sub-carrier signal of the transmission symbol by $(1/A_n)\exp(-j\phi)$ so as to compensate the fading.

An IFFT operation section **62** performs IFFT operation on the number of sub-carriers N of channel estimation values C_0-C_{N-1} which are output from the channel estimation section **61**, and outputs a delay profile which consists of N number of samples per one OFDM symbol period shown in FIG. **7**. Each sample value indicates the intensity of the received wave (direct wave, delay wave) in each path of the multi-paths, and after the delay time M from the FFT window position (=0), each sample value of the delay profile becomes a small value less than the set level. A delay spread detection section **63** detects this delay time M as a delay spread, and outputs it. The delay spread indicates a spread of the multi-paths, and can be used for judging the good/bad receive state of a mobile station. If the delay spread is large, the maximum delay time is large and the receive state is bad, and if the delay spread is small, the maximum delay time is small and the receive state is good.

The above is the case when the mobile station measures the delay spread, and transmits it to the base station, but the base station side can also measure the delay spread of each mobile station. In other words, in a case when the frequency bands of the downlink and uplink are the same or not so different, and it is expected that the delay characteristics of the path are approximately the same in the uplink and downlink, the delay spread estimation section shown in FIG. **6** is installed in the base station.

(D) Variant Form of Base Station

As shown in FIG. **8**, the slot assignment control section **32** may be replaced with a scheduler section **70**. In this case, in the scheduler section **70**, a destination mobile station to which a data packet is transmitted via a predetermined slot, and an encoding scheme and modulation method thereof, are decided, and error correction encoding, data modulation and OFDM modulation are performed accordingly, and the data packet is transmitted as OFDM symbol after a guard interval with a predetermined length is inserted. At this time, the scheduler section **70** does not have to decide the guard interval length. The mobile station, to which a frame format has been reported via a common control channel, knows the guard interval length in each slot in advance, so the guard interval is deleted and FFT processing using this information is performed in the mobile station.

(E) Frame Format Generation Method and Slot Assignment Method

Now a frame format generation method and a slot assignment method will be described. In the following description, it is assumed that the number of users≦the number of slots in a frame (N_{slot}), so as to simplify the description, but if the slot assignment control section **32** is replaced with the scheduler section **70**, as shown in FIG. **8**, this method can also be used for the case of number of users>N_{slot}. In other words, if slot assignment is performed combining with schedule control (priority assignment control based on reception quality of each user), the method can be also used for the case of number of user>N_{slot}.

(a) Definition of Frame Format

It is assumed that the number of slots in a frame N_{slot}, number of slot formats K, and guard interval GI length in slot format #k ($1 \leqq k \leqq K$) T_k have been uniquely defined in the system in advance. To make it easier for the user to assign slots, the slot format #**1**~#k is defined in the sequence of the guard interval length ($T_1 > T_2 > \ldots > T_K$), and the slots are lined up for N_k number of slots ($0 \leqq N_k \leqq N_{slot}$) at a time in the sequence of the lower number in k, so as to form one frame format. Here N_k is the number of slots in a frame having a slot format #k of which GI length is T_k, and is decided according to the distribution of the delay spread, as mentioned later.

FIG. **9** shows an example of a frame format when N_{slot}=5, K=3, N_1=1, N_2=N_3=2. The N_{slot}, K and T_k are uniquely defined in the system, so the frame format can be reported to the mobile station (user) by reporting only N_k for all the slot formats #**1**~#k.

(b) Frame Format Generation Method

FIG. **10** is a flow chart depicting the frame format generation processing of the frame format generation section **33**.

The frame format generation section **33** monitors whether it is necessary to update the frame format (step **101**). For the frame format update timing, (1) in the case of a method of updating periodically, the frame format is updated in this update cycle, and (2), in the case of updating considering the receive environment, the frame format generation section **33** determines the latest delay spread distribution, compares it with the delay spread distribution at a previous frame format update, judges whether an update of the frame format is necessary, and updates it if update is necessary. In this description, it is assumed that the frame format is updated periodically.

If update is necessary, the frame format generation section **33** performs statistics processing for the propagation delay information (delay spread) of each user which is input from the uplink receiver **31**, and determines the distribution function $F(T_{k+1} \leqq d < T_k)$ of the delay spread d ($T_{k+1} \leqq d < T_k$) throughout a predetermined measurement cycle (step **102**). Here k=1~K, $T_1 > T_2 > \ldots > T_K > T_{K+1}$ (=0).

In this case, the distribution function $F(T_{k+1} \leqq d < T_k)$ indicates a ratio of users of which delay spread d is in the range of $T_{k+1} \leqq d < T_k$. The measurement cycle is set to a relatively long cycle so as to follow up the slow change of the delay path environment.

The frame format generation section **33** calculates the number of slots N_k(k=1−K) of a slot format #k in a frame of which GI length is T_k using the following expression, based on the distribution function $F(T_{k+1} \leqq d < T_k)$ determined in step **102** (step **103**).

$$N_K = [F(0 \le d < T_K) \times N_{slot}] \tag{1}$$

$$N_{K-1} = [F(T_K \le d < T_{K-1}) \times N_{slot}]$$

$$\ldots$$

$$N_2 = [F(T_3 \le d < T_2) \times N_{slot}]$$

$$N_1 = N_{slot} - \sum_{k=2}^{K} N_k$$

In equation (1) [x] indicates a maximum integer which does not exceed x.

Then the frame format generation section **33** arranges N_k number of slots which is in proportion to the distribution function $F(T_{k+1} \leqq d < T_k)$ sequentially from the slot format #k with smaller GI length (k=K, K−1, . . . 1), and arranges finally N_1 number of slots for the slot format #1 of which GI length is the maximum, so as to generate the frame format (step **104**). As being obvious from the equation, the accumulated value of the fractions which are rounded off by [•] is inserted to N_1, thereby the slot format of which GI length is longest are assigned with priority.

For example, in the case of N_{slot}=5, K=3, $F(0 \leqq d < T_3)$=20%, $F(T_3 \leqq d < T_2)$=30%, and $F(d \geqq T_2)$=50%, N_1-N_3 are calculated as follows.

$$N_3=[0.2\times 5]=1$$

$$N_2=[0.3\times 5]=1$$

$$N_1=5-2=3 \quad (2)$$

The frame format generation section **33** inputs the generated frame format to the slot assignment control section **32**, guard interval insertion section **34**, and control information base band processing section **35**. The control information base band processing section **35** reports the number of slots N_k (k=1~K) having a slot format #k with GI length T_k in the reported frame format to all the mobile stations in the cell or sector via an information channel (step **105**), and ends the frame format generation processing.

(c) Slot Assignment Method

The slot assignment control section **32** (FIG. **1**) assigns each slot constituting the frame format generated by the frame format generation section **33** to each mobile station (user) according to the following procedure.

(1) The users are rearranged sequentially from a user having the longest delay spread d.

(2) A slot is assigned sequentially to the rearranged users, from a slot of the lower slot format #k having the longer GI length. If the distribution of the number of slots N_k(k=1~N) and the user distribution based on the delay spread match, a slot having GI length closest to the delay spread, out of the GI lengths that satisfy delay spread<GI length, can be assigned to each user.

(3) Even if the distribution of the number of slot N_k(k=1~N) and the user distribution based on the delay spread do not match and delay spread is larger GI length in procedure (2), assignment is continued according to the sequence of the users after the rearrangement.

(4) If all the users with $d \geqq T_{k+1}$ have been assigned to the slots of the GI length T_k ($>T_{k+1}$) and some such slots remain unassigned, the slots are assigned sequentially to the remaining users with $d < T_{k+1}$ in ascending order of the delay spread.

FIG. **11** is a flow chart depicting the slot assignment processing for implementing the above operation.

Here the judgment of whether an empty slot with GI length T_k exists in the above (4) corresponds to the judgment whether "$d_m < T_{k+1}$ and $n \leqq N_1+N_2+ \ldots +N_k$ ($1 \leqq k \leqq K$) are satisfied in step **204**.

When slot assignment starts, the slot assignment control section **32** initializes to m=n=1, m_{max}=M (step **201**). Here m indicates that the target user is the m-th user, and n−1 is the number of slots assigned thus far, and M is the total number of users.

Then the users are rearranged sequentially from a user having a longer delay spread (step **202**), and it is checked whether m≦M (step **203**) and the procedure ends if m=M+1. If m≦M, it is checked whether $d_m < T_{k+1}$ and $n \leqq N_1+N_2+ \ldots +N_k$ ($1 \leqq k \leqq K$) (step **204**) are satisfied. In other words, the range of the delay spread d_m of the m-th user is determined as $d_m < T_{k+1}$, and it is judged whether $n \leqq N_1+N_2+ \ldots +N_k$ is satisfied. If the condition in step **204** is not satisfied, the m-th user is assigned to the n-th slot of the frame format (step **205**), n and m are incremented (step **206**), and processing returns to step **203**.

If the condition in step **204** is satisfied and some slots with GI length Tk remain unassigned, so the m_{max}-th user is assigned to slot n (step **207**), n is incremented, and m_{max} is decremented (step **208**), and processing returns to steps **203**.

Now the slot assignment control will be described using the operation examples shown in (A) and (B) of FIG. **12**. Here it is assumed that the number of slots N_{slot}=5, the number of slot formats K=3, and the number of users M=5. Also in the user numbers after rearrangement, it is assumed that (1) the delay spreads of user **1** and user **2** are in the $T_2 \leqq d < T_1$ range, (2) the delay spread of user **3** is in the $T_3 \leqq d < T_2$ range, and (3) the delay spreads of user **4** and user **5** are in the $0 \leqq d < T_3$ range.

If the distribution of N_k (N_1=2, N_2=1, N_3=2) generated by the frame format generation section **33** matches the above mentioned user distribution of the delay spread, each slot of the frame format can be accurately assigned to the users, as shown in (A) of FIG. **12**, and actual distribution also becomes N_1=2, N_2=1 and N_3=2.

However if the update of the frame format has not followed up the change of the delay spread distribution, and if the distribution of N_k does not match the actual user distribution of the delay spread due to a rounding error generated by round down when N_k of the frame format is calculated, each slot of the frame format cannot be accurately assigned to the users.

Now an operation example in the case of matching and an operation example in the case of a mismatch will be described.

Operation example 1 (see (A) of FIG. **12**): When the distribution of N_k (N_1=2, N_2=1, N_3=2) in the frame format and the user distribution (N_1=2, N_2=1, N_3=2) of the delay spread match, the conditions in step **204** are not established for all users, so in the processing in steps **205** and **206**, slots are assigned from the first one sequentially to the user of which delay spread is longer. As a result, user **1** and user **2** are assigned to the slots with guard interval length T_1, user **3** is assigned to the slot with T_2, and user **4** and user **5** are assigned to the slots with T_3.

Operation example 2 (see (B) of FIG. **12**): In the case where the distribution of N_k (N_1=1, N_2=3, N_3=1) in the frame format and user distribution (N_1=2, N_2=1, N_3=2) of the delay spread do not match, since the delay spread d_1 of the user **1** is in a range of $T_2 \leqq d_1 < T_1$, the conditions in step **204** is satisfied, so the user **1** is assigned to slot **1** (T_1 slot) in the procedure in step **205**.

Like the user **1**, since the delay spread of the user **2** is $T_2 \leqq d_2 < T_1$, also the conditions in step **204**, so is assigned to slot **2** (T_2 slot) in the processing in step **204** is not satisfied, so the user **2**. In this case, assignment to the T_1 slot is desirable but the T_1 empty slot is not, so user **2** is assigned to the T_2 slot.

Unlike the user **2**, the delay spread of the user **3** is in arrange of $T_3 \leqq d_3 < T_2$ but $n=3>N_1$ is established, and also the conditions in step **204** is not satisfied, so the user **3** is assigned to slot **3** (T_2 slot) in the processing in step **205**.

In regard to user **4**, since the delay spread is in a range of $T_4(=0) \leqq d_4 < T_3$ and $n=4=N_1+N_2$, the conditions in step **204** is satisfied, so user **5**, of which delay spread is smallest, is assigned to slot **4** (T_2 slot) in the processing in step **207**.

Thereafter, since m is not incremented in the former processing, so the judgment in step **204** is performed again for user **4**. This time, $T_4(=0) \leqq d_4 < T_3$ and $n=5>N_1+N_2$ is estab-

lished and the conditions in step **204** is not satisfied, so user **4** is assigned to slot **5** (T_3 slot) in the processing in step **205**.

According to the present invention, transmission with a semi-optimum guard interval length becomes possible without transmitting/receiving the guard interval length information frequently, and throughput can be improved.

Also according to the present invention, slot assignment can be continued even in the case when the frame format no longer matches the actual receive state.

What is claimed is:

1. A radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

a receive state acquisition section for acquiring a receive state of each mobile station;

a frame format decision section for deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

a slot assignment section for assigning each slot of the frame format to data for a mobile station, wherein the frame format decision section judges whether it is necessary to update the frame format, and updates the frame format if update is necessary.

2. The radio communication apparatus according to claim **1**, wherein the frame format is decided for each sector or for each cell.

3. The radio communication apparatus according to claim **1**, wherein the slot assignment section assigns each slot of the frame format to data for each mobile station based on a receive state of each mobile station in a cycle shorter than the update period of the frame format.

4. A radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

a receive state acquisition section for acquiring a receive state of each mobile station;

a frame format decision section for deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

a slot assignment section for assigning each slot of the frame format to data for a mobile station, wherein the radio communication apparatus further comprises a frame format reporting section for reporting the decided frame format to mobile stations.

5. A radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

a receive state acquisition section for acquiring a receive state of each mobile station;

a frame format decision section for deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

a slot assignment section for assigning each slot of the frame format to data for a mobile station, wherein the receive state acquisition section acquires a delay spread as a receive state of each mobile station, and the frame format decision section decides the frame format based on the delay spreads of mobile stations.

6. The radio communication apparatus according to claim **5**, wherein the receive state acquisition section acquires the delay spread from a mobile station which has means of estimating a delay spread based on a downlink signal, quantizing the delay spread, and reporting the quantitized delay spread to the base station.

7. The radio communication apparatus according to claim **5**, wherein the receive state acquisition section comprises a delay spread estimation section for estimating a delay spread of each mobile station based on an uplink signal from each mobile station.

8. A radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

a receive state acquisition section for acquiring a receive state of each mobile station;

a frame format decision section for deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

a slot assignment section for assigning each slot of the frame format to data for a mobile station, wherein the receive state acquisition section acquires a delay spread as a receive state of each mobile station, and the frame format decision section prepares a plurality of slot formats of which guard interval lengths are different in advance, determines distribution of the delay spread based on the delay spreads of mobile stations, and assigns a predetermined slot format to each slot constituting the frame according to the distribution of the delay spread to determine the frame format.

9. The radio communication apparatus according to claim **8**, wherein the frame format decision section judges whether it is necessary to update the frame format and updates the frame format if update is necessary, and the slot assignment section assigns each slot of the frame format to data for each mobile station based on a delay spread of each mobile station in a cycle shorter than the update period.

10. The radio communication apparatus according to claim **8**, wherein an effective symbol length of the slot formats of which guard interval lengths are different, is constant.

11. The radio communication apparatus according to claim **8**, wherein a total symbol length of an effective symbol length of the slot formats of which guard interval lengths are different and the guard interval length is constant.

12. The radio communication apparatus according to claim **9**, wherein the slot assignment section assigns mobile station data with small path delay with priority if the mobile station data cannot be assigned to an optimum slot due to the deviation of the delay spread distribution of the mobile stations.

13. The radio communication apparatus according to claim **9**, wherein the slot assignment section assigns mobile station data to a slot even if the guard interval is smaller than the path delay if the mobile station data cannot be assigned to an optimum slot due to the deviation of delay spread distribution of the mobile stations.

14. A communication method for a radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

acquiring a receive state of each mobile station;

deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

assigning each slot of the frame format to data for a mobile station, wherein the deciding frame format further comprises judging whether it is necessary to update the frame format, and updating the frame format if update is necessary.

15. The communication method according to claim **14**, wherein allocating a slot further comprises assigning each slot of the frame format to data for a mobile station based on

a receive state of each mobile station in a cycle shorter than the update period of the frame format.

16. The communication method according to claim **14**, further comprising reporting the decided frame format to each mobile station.

17. A communication method for a radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

acquiring a receive state of each mobile station;

deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

assigning each slot of the frame format to data for a mobile station, wherein the acquiring a receive state further comprises acquiring a delay spread as a receive state of each mobile station, and the deciding a frame format further comprises deciding the frame format based on the delay spread of mobile stations.

18. The communication method according to claim **17**, wherein the acquiring a receive state further comprises a acquiring the delay spread from the mobile station.

19. The communication method according to claim **17**, wherein the acquiring a receive state further comprises estimating a delay spread of each mobile station based on an uplink signal from each mobile station.

20. A communication method for a radio communication apparatus for forming a frame with a plurality of slots, and inserting a guard interval into each slot along with data for a mobile station to perform communication, comprising:

acquiring a receive state of each mobile station;

deciding a frame format of which guard interval length is different for each slot based on the receive state of each mobile station; and

assigning each slot of the frame format to data for a mobile station, wherein the acquiring a receive state further comprises acquiring a delay spread as a receive state of each mobile station, and the deciding a frame format further comprises preparing a plurality of slot formats of which guard interval lengths are different in advance, determining the distribution of the delay spread based on the delay spreads of mobile stations, and assigning a predetermined slot format to each slot constituting the frame according to the distribution of the delay spread, to determine the frame format.

21. The communication method according to claim **20**, wherein the deciding a frame format further comprises judging whether it is necessary to update the frame format and updating the frame format if update is necessary, and the assigning a slot further comprises a assigning each slot of the frame format to data for a mobile station based on a delay spread of each mobile station in a cycle shorter than the update period of the frame format.

22. The communication method according to claim **20**, wherein the assigning a slot further comprises assigning mobile station data with small path delay with priority if the mobile station data cannot be assigned to an optimum slot due to the deviation of delay spread distribution of the mobile stations.

23. The communication method according to claim **20**, wherein the assigning a slot further comprises assigning mobile station data to a slot even if the guard interval is smaller than the path delay if the mobile station data cannot be assigned to an optimum slot due to the deviation of delay spread distribution of the mobile stations.

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